�54 Reduction of power consumption in a mobile station.

�57 The invention relates to a method for reducing the power consumption in a mobile system, the mobile system comprising a base station broadcasting messages such as signaling messages to the mobile stations. The stations comprising receiver means for receiving and processing messages broadcast from the base station. The signaling message is divided in parts and transmitted in a number of time slots in the TDMA system. First only a first predetermined part of a signaling message is received, and the signaling message broadcast from the base station is reconstructed on the basis of the part of the signaling message only, and the receiving of the rest of the signaling message is discontinued by switching at least a part of the receiver means of the mobile station in a power saving mode during the said period. If necessary, more information of the signaling message can be received before the reconstruction of the signaling message.
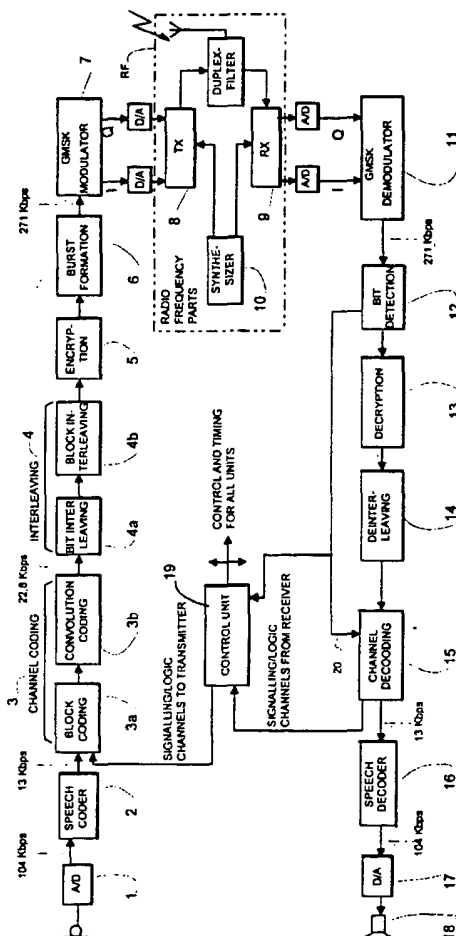
Fig. 2

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Th pr sent inv ntion relates to a meth d and apparatus for reducing the power consumption of a mobile station in a cellular radio system.

Known cellular radio systems include a plurality of base stations for providing service in predetermined geographical areas, or cells. Mobile stations situated in the cells are serviced by one or more base stations covering that particular cell.

A mobile station will typically operate in one of two modes depending on the needs of the user. When the user is making a telephone call the mobile station is said to be in dedicated mode in which the mobile station is actively transmitting and receiving on a channel allocated for its own use. However at any other time when the mobile station is powered up the mobile station is said to be in idle mode and may be contacted by other users. In idle mode the mobile station is still in contact with the base station but there is no dedicated channel for sending and receiving speech or data. Contact is achieved with the base station through the mobile station listening to broadcast channels which constantly update the mobile stations within the cell with necessary information.

Methods of transmitting and receiving speech and data in dedicated mode are known in the art and are detailed with reference to the GSM (Groupe Speciale Mobile) system in the publication M.R.L. Hodges "The GSM radio interface, British Telecom Technological Journal", Vol. 8, No 1, 1990, p. 31 - 43, section 4, the content of which is hereby incorporated by reference.

For handheld mobile stations which are battery powered the maximum time in which the mobile station can operate in idle mode is typically about 16 hours. For a similar mobile station in dedicated mode the maximum operational time is typically about 1 to 2 hours. These periods of operation are dependent almost entirely on the power consumption of the mobile station in the respective modes. A reduction of the power consumption in either mode would result in increased operational times. In idle mode the main contributor to the power consumption typically comes from the RF (Radio Frequency) sections of the mobile station. Therefore to reduce power consumption it is favorable for the RF section to only be on for limited periods of time. As the main purpose of the RF section in idle mode is to listen to broadcast messages it is further noted that the receiving side of the RF section is the most significant.

Generally broadcast messages sent by a base station which are specific to one mobile station will normally be received by all the mobile stations in idle mode within the cell. This obviously has an adverse ffect on the operational tim of thes mobile station and to this avail European patent publication EP 473465 sugg st that for messages containing an identifying part and an information part, the mobile station first receives and decodes the identifying

part. If the mobile station then discovers that th m s-sage is intend d for its If th information part is further received and decoded. However, if the mobile station discovers that the m ssag is intend d for another mobile station the receiving circuits are switched to power saving mode during reception of the information part. Battery saving according to EP 473 465 is therefore based on a method for receiving two-word message, the first word of which contains the address. If this address indicates that the message is intended for another mobile station then, according to EP 473 465, it is not necessary to receive the second word of the message. Thus it is possible for the mobile station to switch a considerable part of its receiving circuits into the power saving mode until the next message is expected to arrive. This power saving mode is controlled by a timing circuit, which may be programmed with the time intervals between messages. The receiving of a message according to EP 473 465 is discontinued on the basis of receiving an address part of a complete message.

The prior art will now be discussed further with reference to the GSM system of communication. However, it should be noted that the invention is not restricted purely to this system but that reference to the GSM system aids a clear description and understanding of the state of the art for the present invention.

The idle mode and the dedicated mode in the GSM system have two classes of channels associated with them, notably dedicated channels for dedicated mode and common channels for idle mode. Referring to the common channels used in idle mode the most frequently used are the downlink channels, i.e. the channels for sending information from the base station to the mobile station. These are divided still further into channels for control information such as the FCCH (Frequency Correction CHannel) and the SCH (Synchronisation CHannel) and those for sending messages, the BCCH (Broadcast Control CHannel) and PCH (Paging CHannel). It is these downlink channels the mobile station listens to and they represent the main power consumption when in idle mode. The form of these channels are shown in figure 3.

The BCCH and PCH are similar in that they are encoded in exactly the same way and are sent over the same number of TDMA (Time Division Multiple Access) frames. However, the actual messages they convey differ substantially. The BCCH is used for sending messages to all mobile stations, relating to, for example, cell selection, network identification, as well as others. The PCH is used for paging specific mobile stations but is nevertheless monitored by all mobile stations within th cell. To describe how thes m ssages are rec ived it is nec ssary to first understand th basics of how these messages are transmitted.

Firstly th PCH or BCCH messag originates in

digital f rm from the infrastructure of the GSM system. From there channel coding is performed on the data which introduces redundancy into the message by adding extra information relating to the original data. This allows messag s to be reconstructed ven when information is lost over the radio link. The channel encoded message is then interleaved to mix up the data within the message in a predetermined way. Following this the message is then encrypted, formatted for burst formation, modulated, then transmitted. The resulting message is transmitted in four transmission bursts (timeslots) in four consecutive TDMA frames.

Mobile stations in idle mode receive all the four timeslots corresponding to the complete message. Then the message is reconstructed according to the inverse operations of the transmission. The process involves receiving the signal from the antenna, demodulating the signal, de-encrypting the message, de-interleaving the message, then channel de-coding the message. The result is the original message sent from the base station.

According to a first aspect of the present invention there is provided a method for controlling the power consumption of a mobile station in a cellular radio system, the method comprising the steps of: a) receiving a first predetermined portion of a message; b) determining a reconstruction accuracy for the message corresponding to the received portion of the message; and c) receiving a next predetermined portion of the message and returning to step b) if the reconstruction accuracy fails to fulfil a predetermined criterion and the complete message has not been received, and according to a second aspect of the present invention there is provided an apparatus for controlling the power consumption of a mobile station in a cellular radio system, the apparatus comprising; a) a receiving means for receiving a portion of a message; and b) determining means for determining a reconstruction accuracy for a message corresponding to the received portion of the message; and c) means for deciding if a reconstruction accuracy for a message fulfils a predetermined criterion.

A method and apparatus in accordance with the invention has an advantage that if the reconstruction accuracy meets with the predetermined criterion then the message can be reconstructed based only on the received portion of the message.

In a preferred method there further comprises a step d) initiating switching of the mobile station into a power saving mode during a time period reserved for a remaining portion of the message provided the complete message has not been received, and in a preferred apparatus ther further compris s means for activating a power saving mod in th mobil station operable for the reconstruction accuracy fulfilling the predetermined criterion.

An advantage of the preferred method and appa-

ratus is that the receiving of th complete message can be discontinued by initiating switching to a pow r saving mode. Thus pow r consumption of th mobile station can be reduced relative to th prior art. In idl mode the main contributor t the power consumpti n typically comes from the RF (Radio Frequency) sections of the mobile station. Therefore to reduce power consumption it is favorable for the RF section to only be on for limited periods of time. As the main purpose of the RF section in idle mode is to listen to broadcast messages it is further noted that the receiving side of the RF section is the most significant.

In a suitable method the reconstruction accuracy is determined by a measurement of the reliability of data from the received portion of the message.

This method allows the reconstruction accuracy to be determined by such measurements as the signal to noise ratio of the received portion of the message.

In another method the reconstruction accuracy is determined by reconstructing the message based on the received portion of the message and detecting the correctness of this reconstruction.

This method allows use of channel codes, which can detect the correctness of a reconstruction, to determine the reconstruction accuracy.

In a preferred method the message is coded to contain redundant data, is interleaved over four time slots, and is broadcast for reception by mobile stations in idle mode.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a block diagram of state of the art transmit/receive sections of a mobile station operating in a GSM system;

Figure 2 shows a block diagram of the transmit/receive sections of a mobile station operating in a GSM system in accordance with the invention;

Figure 3 shows a diagram representing the format of the common channels used in idle mode;

Figure 4 shows a flow chart of the encoding of common channel messages in a base station;

Figure 5 shows a diagram of the interleaving of common channel messages;

Figure 6 shows a FORTRAN code for de-convoluting a message in accordance with the invention.

To gain a greater understanding of the invention the common channels used for downlinking in idle mode of the GSM system will be described here in greater detail.

The GSM system is based on TDMA (Time Division Multiple Access) with FDMA (Frequency Division Multiple Access) and some fr qu ncy hopping. For simplicity th common channels in idle mode all reside on a single frequ ncy known as the 'beacon fre-

quency' and are divided into channels by their position in time, often referred to as th ir allocated timeslots. The gen ral organisation of th common channels is based on a 51 TDMA fram cycle, each TDMA frame comprising 8 timeslots.

Referring to figure 3 there is shown the format of the common channels within the 51 TDMA frame cycle. Each frame of the 51 TDMA frames (apart from frame 50 which is an idle frame) has a channel associated with it. However the actual data associated with that channel is sent only on the first timeslot of the eight timeslots in each TDMA frame. The BCCH (Broadcast Control Channel) and PCH (Paging Channel) use 40 timeslots in each 51 TDMA frame cycle, these timeslots being built as 10 groups of 4 timeslots each. A single group comprising 4 timeslots is said to contain all the information from a single BCCH or PCH message. The first group (frames 2-5) in the cycle is used for a BCCH message whilst the 9 other subsequent groups (frames 6-9, 12-15, 16-19, 22-25, 26-29, 32-35, 36-39, 42-45, 46-49) are used for PCH messages. Other timeslots in the cycle are reserved for the FCCH (Frequency Control Channel), used to ensure that the correct 'beacon frequency' is used by the mobile station, and the SCH (Synchronisation Channel), used to maintain synchronisation of the mobile station's internal clock with that of the base station.

As mentioned previously the PCH and BCCH channels are encoded and transmitted in exactly the same way, each message originating as a data packet of 184 bits and proceeding as shown in figure 4. The first two steps involve applying channel coding to the 184 bit message. The first code used is the FIRE code which is a form of CRC (Cyclic Redundancy Check) and is dedicated to the detection and correction of burst-like errors. The FIRE code increases the redundancy of the 184 bit message by an extra 40 bits. Following this is the convolution coding which is only used for correction purposes. This form of coding is extremely efficient but also doubles the size of the message form 228 bits to 456 bits. These 456 bits are then interleaved such that the bits are shuffled around in a predetermined way and are then divided into a succession of 4 blocks, each containing 114 bits. This form of interleaving is known as block rectangular interleaving and is shown diagrammatically in Figure 5. Usually transmission errors occur as error bursts, therefore the object of the interleaving process is to spread the errors evenly over the transmitted data, allowing the channel decoding in the receive sequence to achieve error correction more efficiently. During de-interleaving in the receive sequence an error burst is conv rted into single error bits, which can be correct d more asily by the channel decoding. The next st p in th transmission sequenc is the data encryption. The encryption is performed by an algorithm individually on each of the 4 blocks output

by the interleaving process. Th encryption prevents unauthorised list ners from eavesdropping on conversations, a problem associated with analogu systems. The 4 ncrypted data blocks are formed into 4 transmission bursts by adding to them a training sequence, trailing bits and a protection period. The transmission bursts are supplied at a far higher data bit rate to a GMSK modulator, which modulates the 4 bursts for the transmission. The GMSK modulation method (Gaussian Minimum Shift Keying) is a digital modulation method with a constant amplitude, where the information is contained in phase shifts. With the aid of one or several intermediate frequencies the transmitter up-converts the 4 modulated bursts to 900 MHz, and transmits them through the antenna and onto the radio path. Each timeslot in figure 3 corresponds to one of these bursts, with the group of 4 timeslots corresponding to the 4 bursts produced by transmission of one message.

Receiving of a PCH or BCCH message is conventionally the inverse of the transmission sequence with the complete number of timeslots corresponding to the complete message being received before the reconstruction of the message is attempted. In accordance with the invention receiving a PCH or BCCH message using less than four timeslots may be achieved.

Referring to figure 2 the antenna of the RF section receives the first two timeslots of the four timeslot PCH or BCCH message. Demodulation 11 is then performed on each of the 2 received timeslots followed by bit detection 12. The bit detection is performed by a channel equaliser which detects the bits in the two received timeslots, i.e. it reproduces the transmitted bit sequence from each of the two timeslots. After the bit detection operation a decryption algorithm is performed on each of the two timeslots followed then by a de-interleaving process. Referring to figure 2 it can be seen that the de-interleaving process which is the inverse of interleaving would normally require all four timeslots to enable complete recovery of the 456 bit coded message. However, in accordance with the invention, the third and fourth timeslots which have not been received are marked as comprising "unreliable" bits, i.e. it is uncertain if they are 1's or 0's. De-interleaving is then performed as normal, yielding a 456 bit message in which the first two bits are "reliable" followed by two "unreliable" bits followed by two "reliable" bits and so on. The next process in the receiving sequence is the de-convolution of the 456 bit message. One method in accordance with the invention would be to use the standard Viterbi code used to de-convolute fully received messages in which many of the bits are "reliabl " bits. This method would r trieve in full th 228 bits of information required. However as only half th 456 bits are "reliable" the rror corr ction proc sses used in the Viterbi decoding would b unlik ly achiev any

worthwhile results. A mor efficient de-convolution cod applicabl when no error correction is used and when only half th data is "r liable" is pres nted in th FORTRAN code of figur 6. This cod was written for use in this method using information giv n in the publication Y-M. Wang, S. Lin "A Modified Selective-Repeat Type-II Hybrid ARQ. System and Its Performance Analysis", IEEE Transactions on communications, Vol. COM-31, No. 5, 1983, p. 593 - 608, the content of which is hereby incorporated by reference.

The 228 bit message is then operated on by the FIRE code which is able to perform a limited amount of error correction. Another feature of the FIRE code though is that it gives a very good indication of whether a message has been reconstructed correctly. To reconstruct a 184 bit message by receiving 228 bits of the two received timeslots the data must contain few errors. If too many errors existed such that the FIRE code detected an incorrect reconstruction then the method according to the invention suggests that a further timeslot of the PCH or BCCH message is received, i.e. the third timeslot.

The procedure of receiving the third timeslot is the same as for receiving the first and second timeslots up to the de-interleaving. Upon de-interleaving the third timeslot the extra "reliable" bits can be added to the already de-interleaved 456 bit message to replace half the "unreliable" bits. De-convolution is now possible using error correction such that a more suitable choice of de-coder would be to use a Viterbi algorithm. As before the 228 bits resulting from the de-convolution are operated on by the FIRE code and the reconstructed 184 bit message is detected for incorrect reconstruction. If the reconstruction was still not correct based on the first, second and third timeslots then the fourth timeslot is received and the reconstruction is performed as in the prior art.

During the receiving of a PCH or BCCH message in accordance with the invention the message may have been reconstruction after receiving only 2 of the 4 timeslots or only 3 of the 4 timeslots. Therefore it is possible to switch the receiving RF sections to a power saving mode during the period of reception of the remaining timeslots of the message. The receiver can be switched in the power saving mode by, for example, the control unit 19 shown in figure 2. It is already known that a receiver comprising both an RF receiver 9 and digital receiver sections (A/D converters and sections 11 - 16) can be switched in the power saving mode when it is not receiving a message. Thus, if the receiving of a PCH or BCCH message is discontinued after receiving a part of the message, the RF receiver 9 can be switched into power saving mode during the tim when the rest of th m ssage is arriving. A power saving mode like this can be realised in a number of differ nt ways, as is known in the art. For instance, it is possible to disconnect all voltages from the RF receiver, r all operating voltag-

s can b disconn cted and the internal circuits of the RF r ceiver left in a state consuming little power.

An enhanced method of receiving the PCH or BCCH messag in accordanc with the inv ntion would be to include a coarse filtering of the data before it entered the reconstruction phase. A by-product of the bit detection (channel equaliser) is information relating to the signal to noise ratio of each burst processed. To implement the enhanced method a series of simulations may be performed on 2 and 3 timeslot portions of 4 timeslot messages with a range of signal to noise ratio values. The threshold values for which satisfactory rates of reconstruction are achieved by the channel decoding would then be recorded and programmed into the mobile station. As shown in figure 2 the mobile station could include an output 20 from the bit detection 12 to convey to the channel decoding section 15, and also the control unit 19, information relating to the likelihood of correct reconstruction given the portion of the message received. If the likelihood is below the threshold value then no reconstruction would even be attempted using the received portions. Instead, the next timeslot would be received and the detection repeated. Alternatively, if the likelihood exceeded the threshold value then reconstruction of the message would be attempted using the received portions as discussed earlier. Other coarse filtering techniques could also be included along the receiving path using extra detection means, for example, a signal to noise ratio detector arranged in front of the channel decoding section.

In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention. For example, the invention is not restricted to the PCH or BCCH messages in the GSM system, but it may be applied also to other systems (e.g. to Code Division Multiple Access systems), in which the signaling messages have sufficient redundancy and the messages are transmitted in parts (time slots).

The scope of the present disclosure includes any novel feature or combination of features disclosed therein either explicitly or implicitly or any generalisation thereof irrespective of whether or not it relates to the claimed invention or mitigates any or all of the problems addressed by the present invention. The applicant hereby gives notice that new claims may be formulated to such features during prosecution of this application or of any such further application derived therefrom.

Claims

1. A method for controlling the power consumption of a mobile station in a cellular radio syst m, th method comprising th steps of:
　　a) receiving a first predet rmined p rtion of a

m ssage;

b) determining a reconstruction accuracy for the message corresponding to th received portion of the message; and

c) receiving a next predetermined portion of the message and returning to step b) if the reconstruction accuracy fails to fulfil a predetermined criterion and the complete message has not been received.

2. A method as claimed in claim 1, wherein the method further comprises a step d) initiating switching of the mobile station into a power saving mode during a time period reserved for a remaining portion of the message provided the complete message has not been received.

3. A method as claimed in claims 1 or 2, wherein the reconstruction accuracy is determined by a measurement of the reliability of data from the received portion of the message.

4. A method as claimed in claims 1 or 2, wherein the reconstruction accuracy is determined by reconstructing the message based on the received portion of the message and detecting the correctness of this reconstruction.

5. A method as claimed in any preceding claim, wherein the message is coded to contain redundant data.

6. A method as claimed in any preceding claim, wherein the message is a broadcast message for reception by mobile stations in idle mode.

7. A method as claimed in any preceding claim, wherein the message is broadcast in an interleaved form over four timeslots.

8. A method as claimed in any preceding claim, wherein the first predetermined portion of the message is two timeslots.

9. A method as claimed in any preceding claim, wherein the next predetermined portion of the message is a single timeslot.

10. An apparatus for controlling the power consumption of a mobile station in a cellular radio system, the apparatus comprising:

a) a receiving means for receiving a portion of a message; and

b) det rmining m ans for d termining a r construction accuracy for a m ssag corr sponding to th r ceived portion of the m s-sag ; and

c) m ans for deciding if a reconstruction ac-

curacy f r a message fulfils a pr determined criterion.

11. An apparatus as claimed in claim 10, wherein the apparatus further comprises means for activating a power saving mode in the mobile station operable for the reconstruction accuracy fulfilling the predetermined criterion.

12. An apparatus as claimed in claims 10 or 11, wherein the determining means comprises a signal to noise ratio detector.

13. An apparatus as claimed in claims 10 or 11, wherein the determining means comprises a means for reconstructing a message given only a portion of the message.
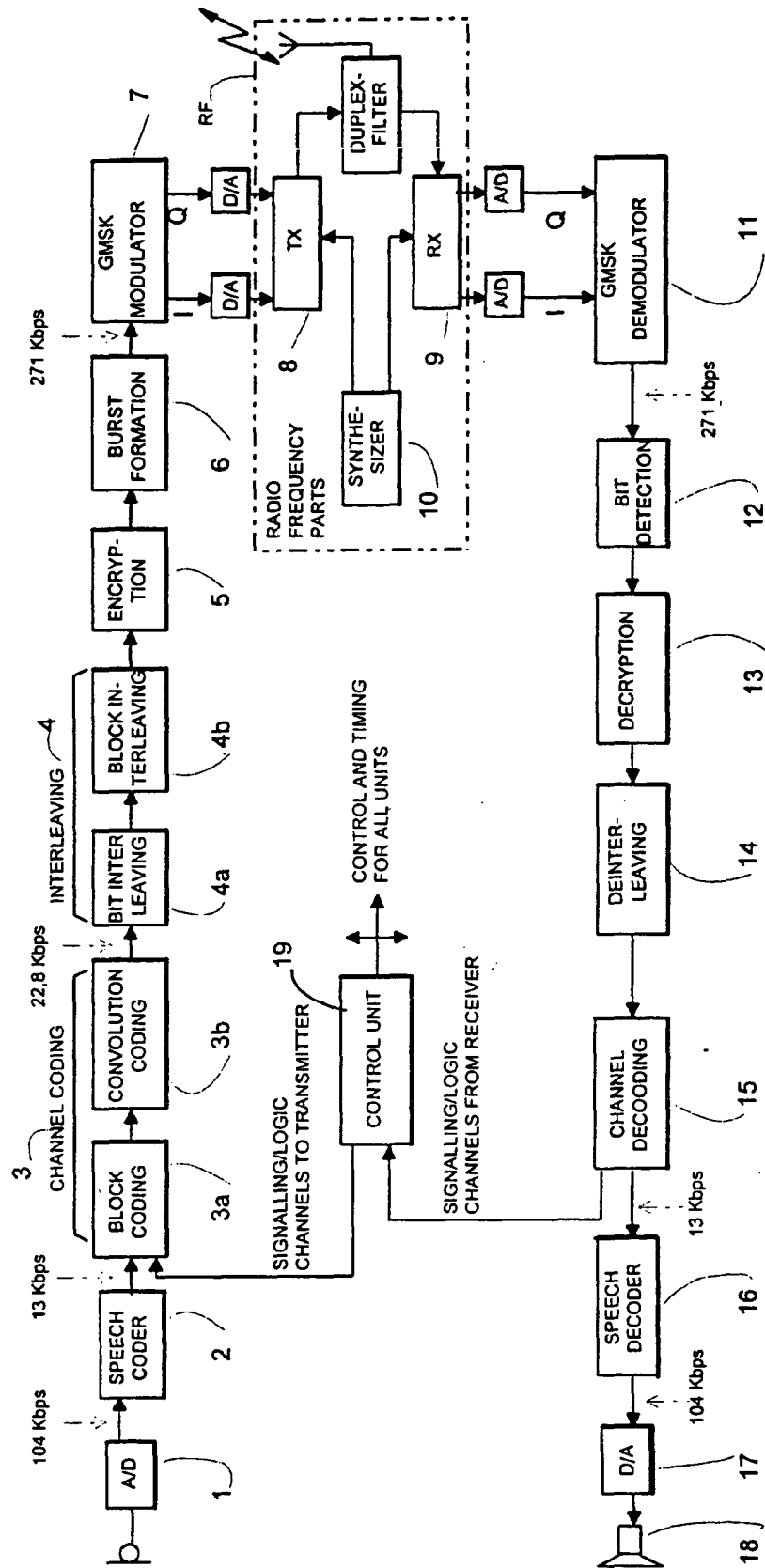
Fig. 1

Fig. 2

Fig. 3

TDMA Fram	Channel	
0	FCCH	
1	SCH	
2	BCCH	
3	BCCH	
4	BCCH	
5	BCCH	
6	PCH	
7	PCH	
8	PCH	
9	PCH	
10	FCCH	
11	SCH	
12	PCH	
13	PCH	
14	PCH	
15	PCH	
16	PCH	
17	PCH	
18	PCH	
19	PCH	
20	FCCH	
21	SCH	
22	PCH	
23	PCH	
24	PCH	
25	PCH	
26	PCH	
27	PCH	
28	PCH	
29	PCH	
30	FCCH	
31	SCH	
32	PCH	
33	PCH	
34	PCH	
35	PCH	
36	PCH	
37	PCH	
38	PCH	
39	PCH	
40	FCCH	
41	SCH	
42	PCH	
43	PCH	
44	PCH	
45	PCH	
46	PCH	
47	PCH	
48	PCH	
49	PCH	
50	-	

Fig. 4

```
┌─────────────────────────────┐
│    PCH/BCCH Message         │
│        184 bits             │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│    FIRE code + tail         │
│       in : 184 bits         │
│       out : 228 bits        │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│    Convolution code         │
│        rate 1/2             │
│      in : 228 bits          │
│     out : 456 bits          │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│      Interleaving           │
│      in : 456 bits          │
│    out : 4 x 114 bits       │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│     Burst   Formation       │
│   in : 4 x 114 bits         │
│  out : 4 x 114 bit bursts   │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│       Encryption            │
│  in : 4 x 114 bit bursts    │
│  out : 4 x 114 bit bursts   │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│      Modulation             │
└─────────────────────────────┘
              │
              ↯
```

Fig. 5

456 bits

REORDERING

Reordered
456bits

PARTITIONING

SUB BLOCKS: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |

BURSTS: 1ST 2ND 3RD 4TH

—— = even bits in burst

- - - = odd bits in burst

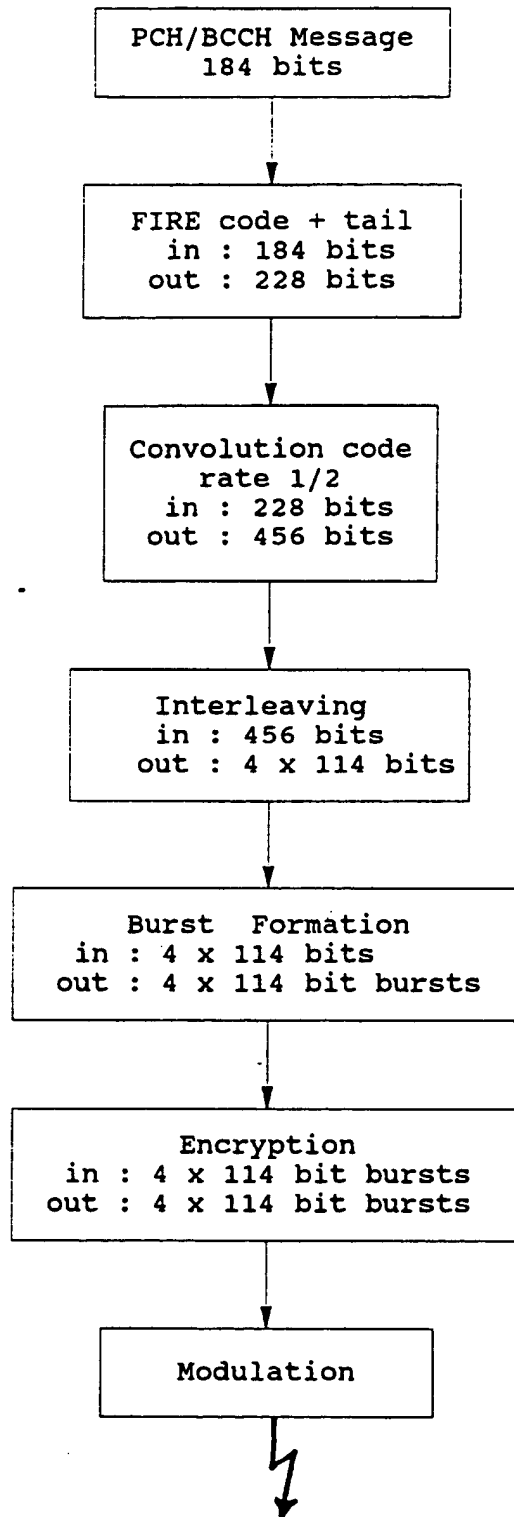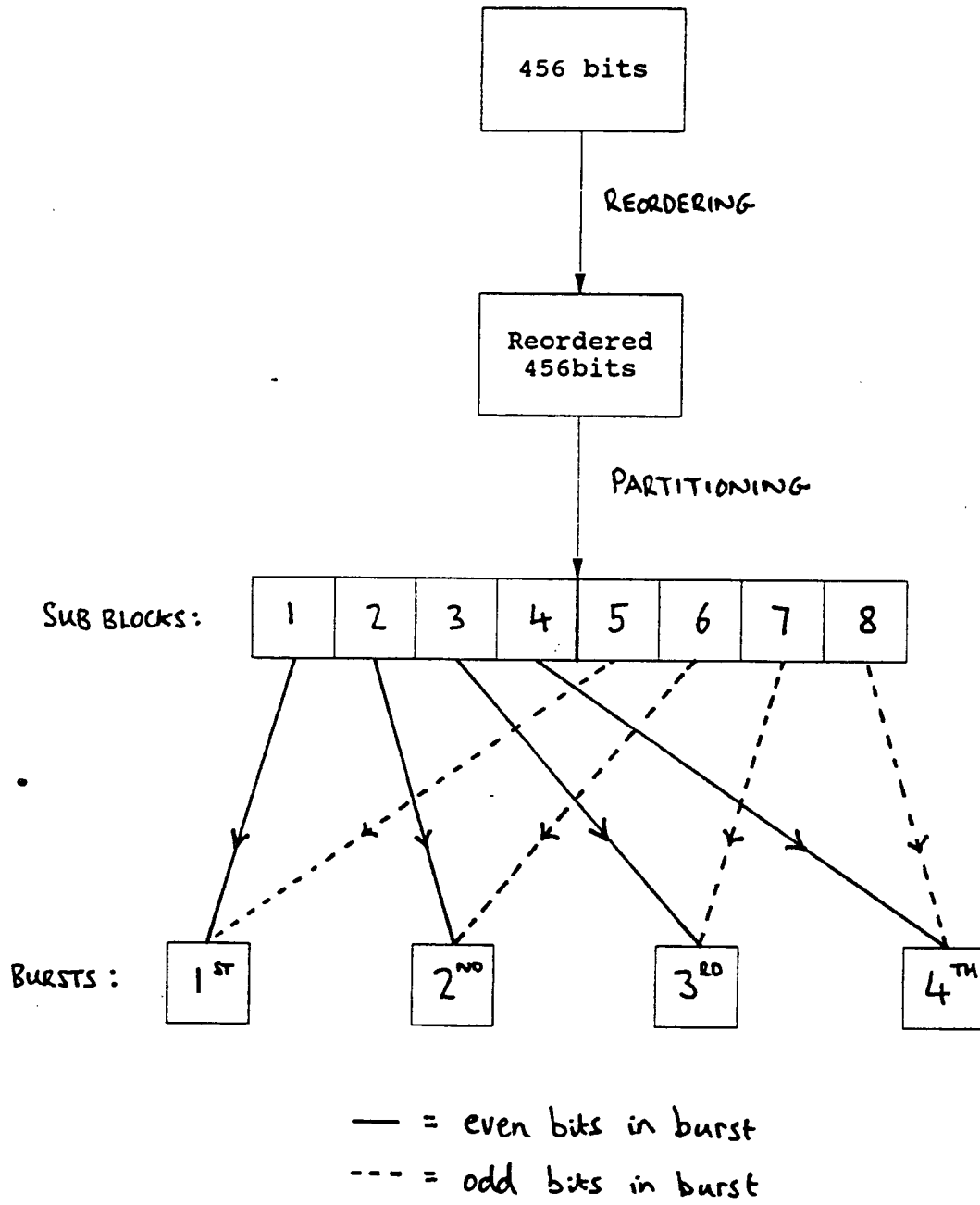## Fig. 6

```
*      10            DECONV
*
*      10.1          FUNCTIONAL DESCRIPTION
*      Subroutine for 2 slot deconvolution
       subroutine DECONV (bitbfr, symb)
*
*      10.2          VARIABLES
*      IMPLICIT NONE
*      10.2.1        EXTERNAL VARIABLES
*      10.2.1.1      INPUTS
       integer bitbfr (456)
*      10.2.1.1.     OUTPUTS
       integer symb (300)
*      10.2.2        LOCAL VARIABLES
       integer deco (2)
       integer orig (0:300)
       integer ik,m,n,cl,c2,c3
*      10.2.3        COMMON VARIABLES
       REAL PI,PI2                    !* constants: pi & 2*pi
       COMMON/MATH/PI,PI2
       INTEGER DEBTX,DEBCH,DEBRX,DEBUG,DEBERR
       COMMON/DEBUG/DEBTX,DEBCH,DEBRX,DEBUG,DEBERR
       INTEGER LOGNUT, FITUNT,DTXUNT,DRXUNT,DEBUNT,DERUNT,DCHUNT
       COMMON/UNIT/LOGUNT,FITUNT,DTXUNT,DRXUNT,DEBUNT,DERUNT,DCHUNT
*
*      10.3  STRUCTURE
*      DECONV
*
*      10.4  MODULE
C      m:  decoder uses odd (m = 0) or even (m = 2)
       m = 0
       cl = 0
       c2 = 0
       c3 = 0
       deco(1) = 0
       deco(2) = 0
       n = 1
       do ik = 1 + m,456 + m,4
              deco(1) = bitbfr(ik)
              deco(2) = bitbfr(ik + 1)
              orig(n + 3)   = deco(1).neqv.deco(2)
              orig(n + 4)   = cl.neqv.c2.neqv.deco(1)
                 cl         = c3
                 c2         = orig(n + 3)
                 c3         = orig(n + 4)
              n = n + 2
       end do
       do n = 1,228
              symb(n)  = orig(n + 4)
       end do
       RETURN
       END
```

EUROPEAN PATENT APPLICATION

(12)

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(54)   **Reduction of power consumption in a mobile station**

(57)   The invention relates to a method for reducing the power consumption in a mobile system, the mobile system comprising a base station broadcasting messages such as signaling messages to the mobile stations. The stations comprising receiver means for receiving and processing messages broadcast from the base station. The signaling message is divided in parts and transmitted in a number of time slots in the TDMA system. First only a first predetermined part of a signaling message is received, and the signaling message broadcast from the base station is reconstructed on the basis of the part of the signaling message only, and the receiving of the rest of the signaling message is discontinued by switching at least a part of the receiver means of the mobile station in a power saving mode during the said period. If necessary, more information of the signaling message can be received before the reconstruction of the signaling message.

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(54) Reduction of power consumption in a mobile station.

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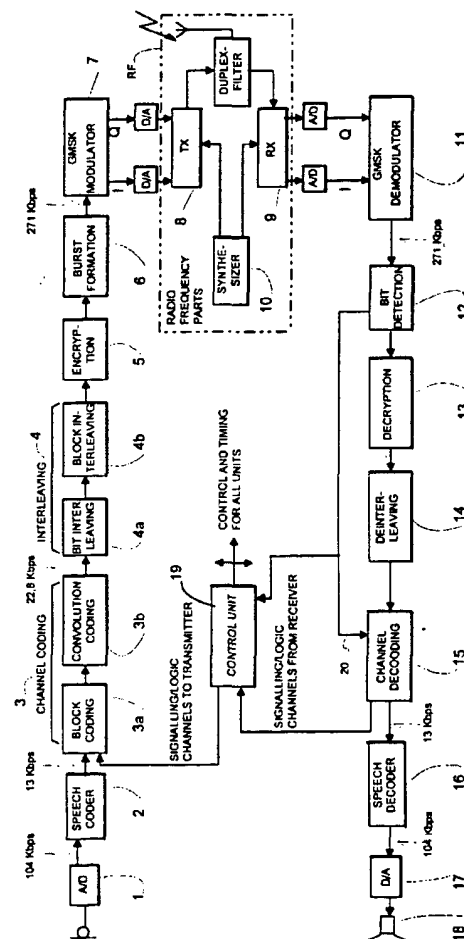
Fig. 2

EP 0 673 175 A2

Th present invention r lates to a method and apparatus for r ducing the pow r consumption of a mobile station in a cellular radio syst m.

Known c llular radio systems include a plurality of base stations for providing service in predetermined geographical areas, or cells. Mobile stations situated in the cells are serviced by one or more base stations covering that particular cell.

A mobile station will typically operate in one of two modes depending on the needs of the user. When the user is making a telephone call the mobile station is said to be in dedicated mode in which the mobile station is actively transmitting and receiving on a channel allocated for its own use. However at any other time when the mobile station is powered up the mobile station is said to be in idle mode and may be contacted by other users. In idle mode the mobile station is still in contact with the base station but there is no dedicated channel for sending and receiving speech or data. Contact is achieved with the base station through the mobile station listening to broadcast channels which constantly update the mobile stations within the cell with necessary information.

Methods of transmitting and receiving speech and data in dedicated mode are known in the art and are detailed with reference to the GSM (Groupe Speciale Mobile) system in the publication M.R.L. Hodges "The GSM radio interface, British Telecom Technological Journal", Vol. 8, No 1, 1990, p. 31 - 43, section 4, the content of which is hereby incorporated by reference.

For handheld mobile stations which are battery powered the maximum time in which the mobile station can operate in idle mode is typically about 16 hours. For a similar mobile station in dedicated mode the maximum operational time is typically about 1 to 2 hours. These periods of operation are dependent almost entirely on the power consumption of the mobile station in the respective modes. A reduction of the power consumption in either mode would result in increased operational times. In idle mode the main contributor to the power consumption typically comes from the RF (Radio Frequency) sections of the mobile station. Therefore to reduce power consumption it is favorable for the RF section to only be on for limited periods of time. As the main purpose of the RF section in idle mode is to listen to broadcast messages it is further noted that the receiving side of the RF section is the most significant.

Generally broadcast messages sent by a base station which are specific to one mobile station will normally be received by all the mobile stations in idle mode within the cell. This obviously has an adverse effect on the operational tim of thes mobile station and to this avail European patent publication EP 473465 suggest that for messages containing an identifying part and an information part, the mobile station first receiv s and d codes th identifying

part. If the mobile station then discov rs that the m s-sage is int nded for itself the information part is further r ceived and decoded. However, if th mobil station discov rs that th messag is intend d f r an-oth r mobile station th receiving circuits are switch-ed to power saving mode during reception of the in-formation part. Battery saving according to EP 473 465 is therefore based on a method for receiving two-word message, the first word of which contains the address. If this address indicates that the message is intended for another mobile station then, according to EP 473 465, it is not necessary to receive the second word of the message. Thus it is possible for the mobile station to switch a considerable part of its receiving circuits into the power saving mode until the next message is expected to arrive. This power saving mode is controlled by a timing circuit, which may be programmed with the time intervals between messages. The receiving of a message according to EP 473 465 is discontinued on the basis of receiving an address part of a complete message.

The prior art will now be discussed further with reference to the GSM system of communication. However, it should be noted that the invention is not restricted purely to this system but that reference to the GSM system aids a clear description and understanding of the state of the art for the present invention.

The idle mode and the dedicated mode in the GSM system have two classes of channels associated with them, notably dedicated channels for dedicated mode and common channels for idle mode. Referring to the common channels used in idle mode the most frequently used are the downlink channels, i.e. the channels for sending information from the base station to the mobile station. These are divided still further into channels for control information such as the FCCH (Frequency Correction CHannel) and the SCH (Synchronisation CHannel) and those for sending messages, the BCCH (Broadcast Control CHannel) and PCH (Paging CHannel). It is these downlink channels the mobile station listens to and they represent the main power consumption when in idle mode. The form of these channels are shown in figure 3.

The BCCH and PCH are similar in that they are encoded in exactly the same way and are sent over the same number of TDMA (Time Division Multiple Access) frames. However, the actual messages they convey differ substantially. The BCCH is used for sending messages to all mobile stations, relating to, for example, cell selection, network identification, as well as others. The PCH is used for paging specific mobile stations but is nevertheless monitored by all mobil stations within the c ll. To describe how th se messag s are rec ived it is necessary to first und r-stand th basics of how th se messag s ar trans-mitted.

Firstly the PCH r BCCH messag originates in

digital form from the infrastructure of the GSM system. From th r channel coding is p rformed on the data which introduces redundancy into the message by adding xtra information relating to the original data. This allows messages to be reconstructed even when information is lost over the radio link. The channel encoded message is then interleaved to mix up the data within the message in a predetermined way. Following this the message is then encrypted, formatted for burst formation, modulated, then transmitted. The resulting message is transmitted in four transmission bursts (timeslots) in four consecutive TDMA frames.

Mobile stations in idle mode receive all the four timeslots corresponding to the complete message. Then the message is reconstructed according to the inverse operations of the transmission. The process involves receiving the signal from the antenna, demodulating the signal, de-encrypting the message, de-interleaving the message, then channel de-coding the message. The result is the original message sent from the base station.

According to a first aspect of the present invention there is provided a method for controlling the power consumption of a mobile station in a cellular radio system, the method comprising the steps of: a) receiving a first predetermined portion of a message; b) determining a reconstruction accuracy for the message corresponding to the received portion of the message; and c) receiving a next predetermined portion of the message and returning to step b) if the reconstruction accuracy fails to fulfil a predetermined criterion and the complete message has not been received, and according to a second aspect of the present invention there is provided an apparatus for controlling the power consumption of a mobile station in a cellular radio system, the apparatus comprising; a) a receiving means for receiving a portion of a message; and b) determining means for determining a reconstruction accuracy for a message corresponding to the received portion of the message; and c) means for deciding if a reconstruction accuracy for a message fulfils a predetermined criterion.

A method and apparatus in accordance with the invention has an advantage that if the reconstruction accuracy meets with the predetermined criterion then the message can be reconstructed based only on the received portion of the message.

In a preferred method there further comprises a step d) initiating switching of the mobile station into a power saving mode during a time period reserved for a remaining portion of the message provided the complete message has not been received, and in a pref rred apparatus there further comprises means for activating a power saving mode in the mobile station perabl for the reconstruction accuracy fulfilling the pred termined criterion.

An advantage of the preferr d method and appa-

ratus is that the r c iving of the c mplete message can be discontinu d by initiating switching to a power saving mode. Thus power consumption of the mobile station can b reduced relativ to the prior art. In idle mode the main contributor to the power consumption typically comes from the RF (Radio Frequency) sections of the mobile station. Therefore to reduce power consumption it is favorable for the RF section to only be on for limited periods of time. As the main purpose of the RF section in idle mode is to listen to broadcast messages it is further noted that the receiving side of the RF section is the most significant.

In a suitable method the reconstruction accuracy is determined by a measurement of the reliability of data from the received portion of the message.

This method allows the reconstruction accuracy to be determined by such measurements as the signal to noise ratio of the received portion of the message.

In another method the reconstruction accuracy is determined by reconstructing the message based on the received portion of the message and detecting the correctness of this reconstruction.

This method allows use of channel codes, which can detect the correctness of a reconstruction, to determine the reconstruction accuracy.

In a preferred method the message is coded to contain redundant data, is interleaved over four time slots, and is broadcast for reception by mobile stations in idle mode.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a block diagram of state of the art transmit/receive sections of a mobile station operating in a GSM system;

Figure 2 shows a block diagram of the transmit/receive sections of a mobile station operating in a GSM system in accordance with the invention;

Figure 3 shows a diagram representing the format of the common channels used in idle mode;

Figure 4 shows a flow chart of the encoding of common channel messages in a base station;

Figure 5 shows a diagram of the interleaving of common channel messages;

Figure 6 shows a FORTRAN code for de-convoluting a message in accordance with the invention.

To gain a greater understanding of the invention the common channels used for downlinking in idle mode of the GSM system will be described here in greater detail.

The GSM system is based on TDMA (Time Division Multipl Access) with FDMA (Frequency Division Multiple Access) and some frequ ncy hopping. For simplicity the common channels in idle mode all reside on a single fr quency known as the 'b acon fre-

quency' and are divid d into channels by their position in tim , oft n referred to as their allocated timeslots. The g neral organisation of the common channels is based n a 51 TDMA frame cycle, each TDMA frame comprising 8 timesl ts.

Referring to figure 3 there is shown the format of the common channels within the 51 TDMA frame cycle. Each frame of the 51 TDMA frames (apart from frame 50 which is an idle frame) has a channel associated with it. However the actual data associated with that channel is sent only on the first timeslot of the eight timeslots in each TDMA frame. The BCCH (Broadcast Control Channel) and PCH (Paging Channel) use 40 timeslots in each 51 TDMA frame cycle, these timeslots being built as 10 groups of 4 timeslots each. A single group comprising 4 timeslots is said to contain all the information from a single BCCH or PCH message. The first group (frames 2-5) in the cycle is used for a BCCH message whilst the 9 other subsequent groups (frames 6-9, 12-15, 16-19, 22-25, 26-29, 32-35, 36-39, 42-45, 46-49) are used for PCH messages. Other timeslots in the cycle are reserved for the FCCH (Frequency Control Channel), used to ensure that the correct 'beacon frequency' is used by the mobile station, and the SCH (Synchronisation Channel), used to maintain synchronisation of the mobile station's internal clock with that of the base station.

As mentioned previously the PCH and BCCH channels are encoded and transmitted in exactly the same way, each message originating as a data packet of 184 bits and proceeding as shown in figure 4. The first two steps involve applying channel coding to the 184 bit message. The first code used is the FIRE code which is a form of CRC (Cyclic Redundancy Check) and is dedicated to the detection and correction of burst-like errors. The FIRE code increases the redundancy of the 184 bit message by an extra 40 bits. Following this is the convolution coding which is only used for correction purposes. This form of coding is extremely efficient but also doubles the size of the message form 228 bits to 456 bits. These 456 bits are then interleaved such that the bits are shuffled around in a predetermined way and are then divided into a succession of 4 blocks, each containing 114 bits. This form of interleaving is known as block rectangular interleaving and is shown diagrammatically in Figure 5. Usually transmission errors occur as error bursts, therefore the object of the interleaving process is to spread the errors evenly over the transmitted data, allowing the channel decoding in the receive sequence to achieve error correction more efficiently. During de-interleaving in the receive sequence an error burst is conv rted into single rror bits, which can b corrected more asily by the channel d coding. The next st p in the transmission s quenc is the data encryption. Th encryption is performed by an algorithm individually on each of the 4 blocks output

by the int rleaving process. The encrypti n prevents unauthorised listeners from eavesdropping on conversations, a problem ass ciated with analogue systems. The 4 encrypt d data blocks are formed into 4 transmission bursts by adding to th m a training sequence, trailing bits and a protection period. The transmission bursts are supplied at a far higher data bit rate to a GMSK modulator, which modulates the 4 bursts for the transmission. The GMSK modulation method (Gaussian Minimum Shift Keying) is a digital modulation method with a constant amplitude, where the information is contained in phase shifts. With the aid of one or several intermediate frequencies the transmitter up-converts the 4 modulated bursts to 900 MHz, and transmits them through the antenna and onto the radio path. Each timeslot in figure 3 corresponds to one of these bursts, with the group of 4 timeslots corresponding to the 4 bursts produced by transmission of one message.

Receiving of a PCH or BCCH message is conventionally the inverse of the transmission sequence with the complete number of timeslots corresponding to the complete message being received before the reconstruction of the message is attempted. In accordance with the invention receiving a PCH or BCCH message using less than four timeslots may be achieved.

Referring to figure 2 the antenna of the RF section receives the first two timeslots of the four timeslot PCH or BCCH message. Demodulation 11 is then performed on each of the 2 received timeslots followed by bit detection 12. The bit detection is performed by a channel equaliser which detects the bits in the two received timeslots, i.e. it reproduces the transmitted bit sequence from each of the two timeslots. After the bit detection operation a decryption algorithm is performed on each of the two timeslots followed then by a de-interleaving process. Referring to figure 2 it can be seen that the de-interleaving process which is the inverse of interleaving would normally require all four timeslots to enable complete recovery of the 456 bit coded message. However, in accordance with the invention, the third and fourth timeslots which have not been received are marked as comprising "unreliable" bits, i.e. it is uncertain if they are 1's or 0's. De-interleaving is then performed as normal, yielding a 456 bit message in which the first two bits are "reliable" followed by two "unreliable" bits followed by two "reliable" bits and so on. The next process in the receiving sequence is the de-convolution of the 456 bit message. One method in accordance with the invention would be to use the standard Viterbi code used to de-convolute fully received messages in which many of the bits are "reliable" bits. This m thod would retriev in full the 228 bits of information required. How v r as nly half the 456 bits are "reliable" th error correction processes used in the Viterbi decoding would be unlikely achieve any

w rthwhile results. A m re efficient de-conv lution code applicabl when no error correction is used and when only half the data is "r liable" is presented in the FORTRAN code of figure 6. This code was written for use in this method using information given in the publication Y-M. Wang, S. Lin "A Modified Selective-Repeat Type-II Hybrid ARQ. System and Its Performance Analysis", IEEE Transactions on communications, Vol. COM-31, No. 5, 1983, p. 593 - 608, the content of which is hereby incorporated by reference.

The 228 bit message is then operated on by the FIRE code which is able to perform a limited amount of error correction. Another feature of the FIRE code though is that it gives a very good indication of whether a message has been reconstructed correctly. To reconstruct a 184 bit message by receiving 228 bits of the two received timeslots the data must contain few errors. If too many errors existed such that the FIRE code detected an incorrect reconstruction then the method according to the invention suggests that a further timeslot of the PCH or BCCH message is received, i.e. the third timeslot.

The procedure of receiving the third timeslot is the same as for receiving the first and second timeslots up to the de-interleaving. Upon de-interleaving the third timeslot the extra "reliable" bits can be added to the already de-interleaved 456 bit message to replace half the "unreliable" bits. De-convolution is now possible using error correction such that a more suitable choice of de-coder would be to use a Viterbi algorithm. As before the 228 bits resulting from the de-convolution are operated on by the FIRE code and the reconstructed 184 bit message is detected for incorrect reconstruction. If the reconstruction was still not correct based on the first, second and third timeslots then the fourth timeslot is received and the reconstruction is performed as in the prior art.

During the receiving of a PCH or BCCH message in accordance with the invention the message may have been reconstruction after receiving only 2 of the 4 timeslots or only 3 of the 4 timeslots. Therefore it is possible to switch the receiving RF sections to a power saving mode during the period of reception of the remaining timeslots of the message. The receiver can be switched in the power saving mode by, for example, the control unit 19 shown in figure 2. It is already known that a receiver comprising both an RF receiver 9 and digital receiver sections (A/D converters and sections 11 - 16) can be switched in the power saving mode when it is not receiving a message. Thus, if the receiving of a PCH or BCCH message is discontinued after receiving a part of the message, the RF receiver 9 can be switched into power saving mode during th tim when th rest of the m ssage is arriving. A pow r saving mode lik this can b r - alis d in a number of different ways, as is known in the art. For instance, it is possible to disconnect all voltages from the RF receiver, or all operating voltag-

es can be disconnected and th internal circuits of the RF r ceiver left in a state c nsuming little power.

An enhanc d method of receiving the PCH or BCCH messag in accordance with the invention w uld b to include a coarse filtering of the data before it entered the reconstruction phase. A by-product of the bit detection (channel equaliser) is information relating to the signal to noise ratio of each burst processed. To implement the enhanced method a series of simulations may be performed on 2 and 3 timeslot portions of 4 timeslot messages with a range of signal to noise ratio values. The threshold values for which satisfactory rates of reconstruction are achieved by the channel decoding would then be recorded and programmed into the mobile station. As shown in figure 2 the mobile station could include an output 20 from the bit detection 12 to convey to the channel decoding section 15, and also the control unit 19, information relating to the likelihood of correct reconstruction given the portion of the message received. If the likelihood is below the threshold value then no reconstruction would even be attempted using the received portions. Instead, the next timeslot would be received and the detection repeated. Alternatively, if the likelihood exceeded the threshold value then reconstruction of the message would be attempted using the received portions as discussed earlier. Other coarse filtering techniques could also be included along the receiving path using extra detection means, for example, a signal to noise ratio detector arranged in front of the channel decoding section.

In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention. For example, the invention is not restricted to the PCH or BCCH messages in the GSM system, but it may be applied also to other systems (e.g. to Code Division Multiple Access systems), in which the signaling messages have sufficient redundancy and the messages are transmitted in parts (time slots).

The scope of the present disclosure includes any novel feature or combination of features disclosed therein either explicitly or implicitly or any generalisation thereof irrespective of whether or not it relates to the claimed invention or mitigates any or all of the problems addressed by the present invention. The applicant hereby gives notice that new claims may be formulated to such features during prosecution of this application or of any such further application derived therefrom.

Claims

1. A method for controlling the pow r consumption of a mobile station in a c llular radio system, th method comprising th steps of:
    a) r ceiving a first predet rmined portion of a

messag ;

b) d termining a reconstructi n accuracy for th message corresponding to the r c iv d p rtion of the m ssage; and

c) receiving a n xt pr determined portion of the message and returning to step b) if the reconstruction accuracy fails to fulfil a predetermined criterion and the complete message has not been received.

2. A method as claimed in claim 1, wherein the method further comprises a step d) initiating switching of the mobile station into a power saving mode during a time period reserved for a remaining portion of the message provided the complete message has not been received.

3. A method as claimed in claims 1 or 2, wherein the reconstruction accuracy is determined by a measurement of the reliability of data from the received portion of the message.

4. A method as claimed in claims 1 or 2, wherein the reconstruction accuracy is determined by reconstructing the message based on the received portion of the message and detecting the correctness of this reconstruction.

5. A method as claimed in any preceding claim, wherein the message is coded to contain redundant data.

6. A method as claimed in any preceding claim, wherein the message is a broadcast message for reception by mobile stations in idle mode.

7. A method as claimed in any preceding claim, wherein the message is broadcast in an interleaved form over four timeslots.

8. A method as claimed in any preceding claim, wherein the first predetermined portion of the message is two timeslots.

9. A method as claimed in any preceding claim, wherein the next predetermined portion of the message is a single timeslot.

10. An apparatus for controlling the power consumption of a mobile station in a cellular radio system, the apparatus comprising:

a) a receiving means for receiving a portion of a message; and

b) det rmining means for d termining a reconstruction accuracy for a message corr - sponding to the r ceiv d portion of th m s- sag ; and

c) m ans for d ciding if a reconstruction ac-

curacy f r a message fulfils a pr det rmined criterion.

11. An apparatus as claimed in claim 10, wh rein th apparatus further comprises means for activating a power saving mode in the mobile station operable for the reconstruction accuracy fulfilling the predetermined criterion.

12. An apparatus as claimed in claims 10 or 11, wherein the determining means comprises a signal to noise ratio detector.

13. An apparatus as claimed in claims 10 or 11, wherein the determining means comprises a means for reconstructing a message given only a portion of the message.
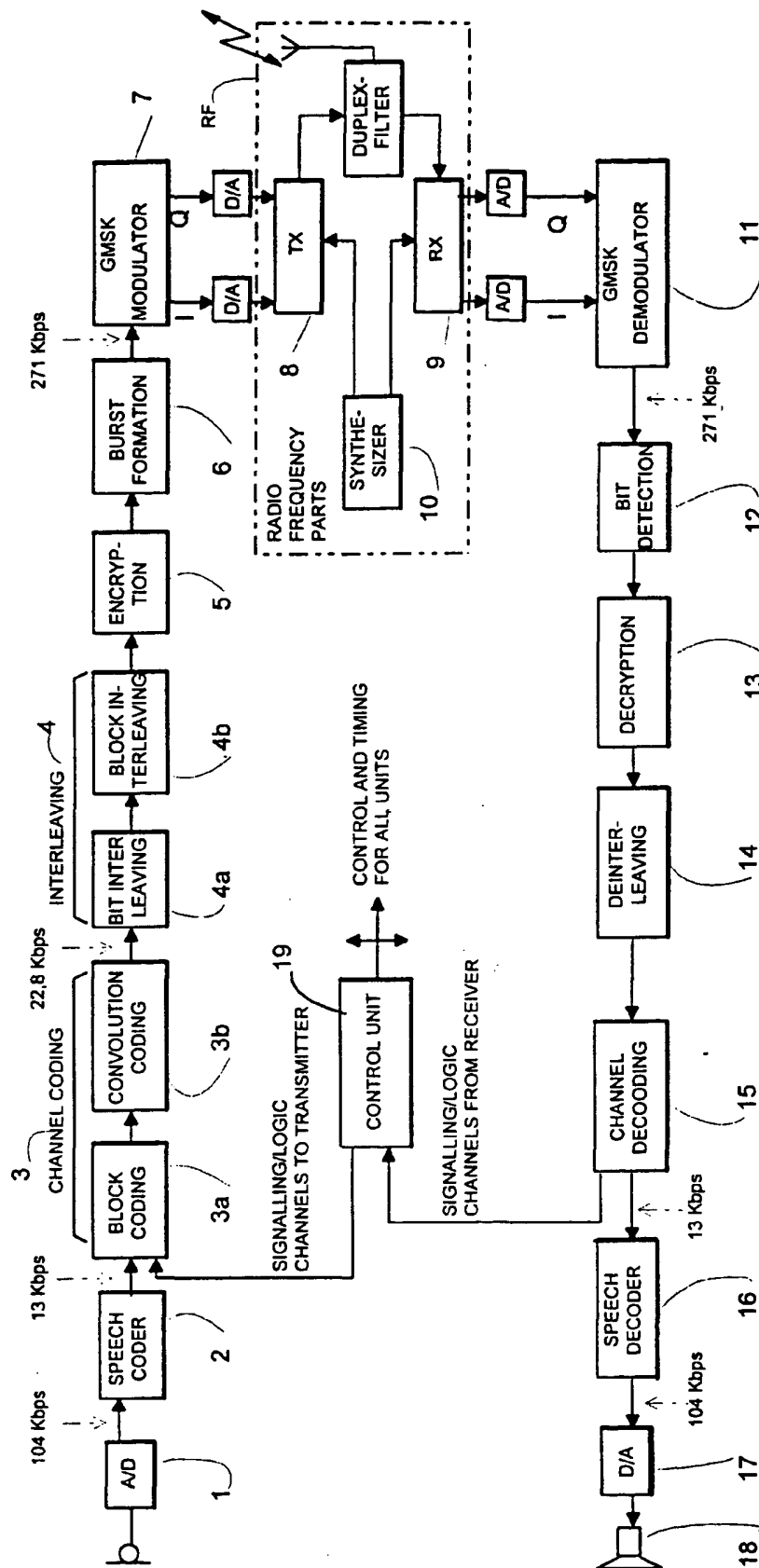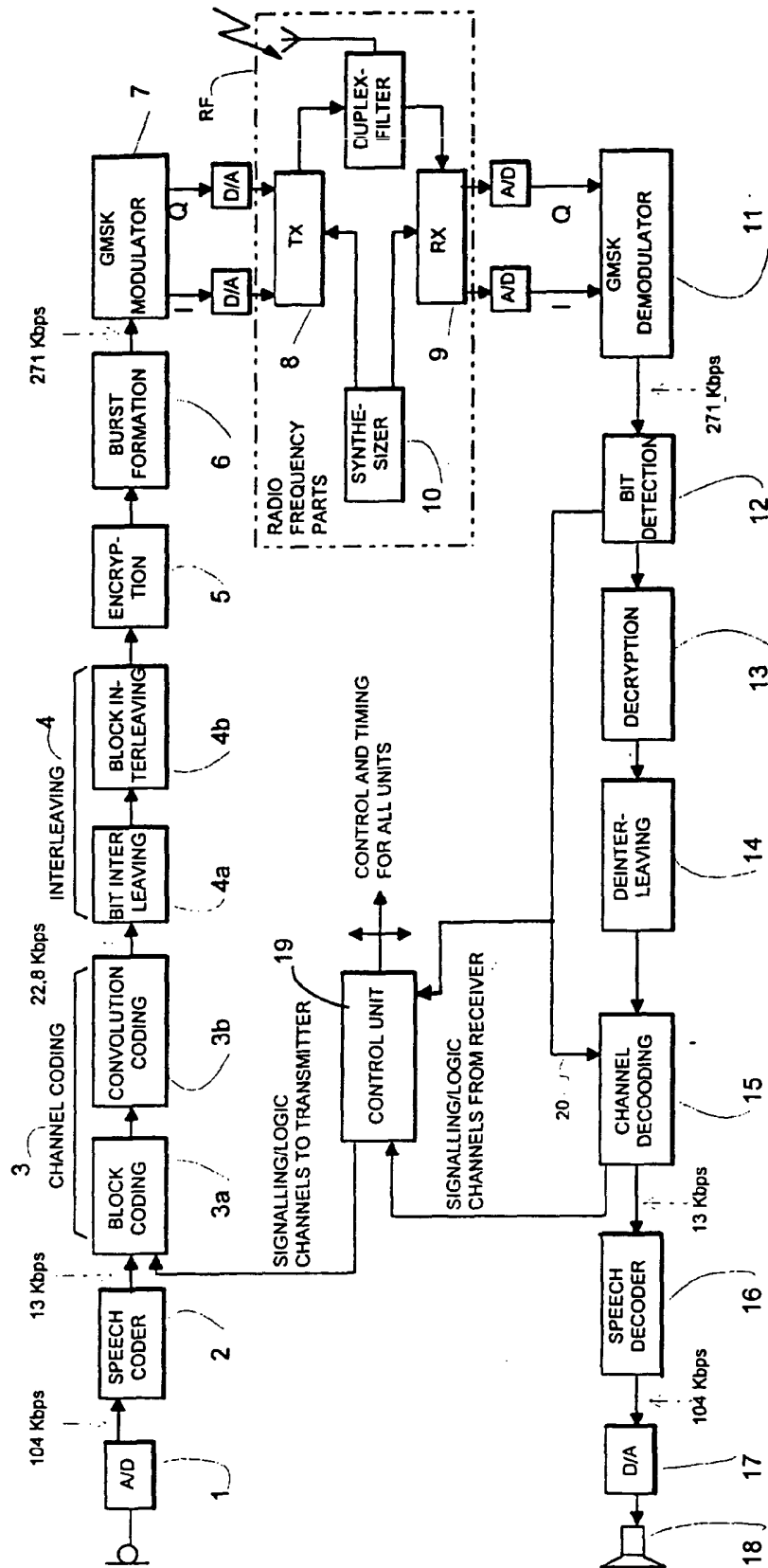
Fig. 1

Fig. 2

Fig. 3

TDMA Frame	Channel	
0	FCCH	
1	SCH	
2	BCCH	
3	BCCH	
4	BCCH	
5	BCCH	
6	PCH	
7	PCH	
8	PCH	
9	PCH	
10	FCCH	
11	SCH	
12	PCH	
13	PCH	
14	PCH	
15	PCH	
16	PCH	
17	PCH	
18	PCH	
19	PCH	
20	FCCH	
21	SCH	
22	PCH	
23	PCH	
24	PCH	
25	PCH	
26	PCH	
27	PCH	
28	PCH	
29	PCH	
30	FCCH	
31	SCH	
32	PCH	
33	PCH	
34	PCH	
35	PCH	
36	PCH	
37	PCH	
38	PCH	
39	PCH	
40	FCCH	
41	SCH	
42	PCH	
43	PCH	
44	PCH	
45	PCH	
46	PCH	
47	PCH	
48	PCH	
49	PCH	
50	.	

Fig. 4

```
┌─────────────────────────┐
│   PCH/BCCH Message       │
│      184 bits            │
└─────────────────────────┘
             ╎
             ▼
┌─────────────────────────┐
│   FIRE code + tail       │
│     in : 184 bits        │
│     out : 228 bits       │
└─────────────────────────┘
             │
             ▼
┌─────────────────────────┐
│   Convolution code       │
│       rate 1/2           │
│     in : 228 bits        │
│     out : 456 bits       │
└─────────────────────────┘
             │
             ▼
┌─────────────────────────┐
│     Interleaving         │
│     in : 456 bits        │
│     out : 4 x 114 bits   │
└─────────────────────────┘
             │
             ▼
┌─────────────────────────┐
│    Burst  Formation      │
│   in : 4 x 114 bits      │
│  out : 4 x 114 bit bursts│
└─────────────────────────┘
             ╎
             ▼
┌─────────────────────────┐
│      Encryption          │
│  in : 4 x 114 bit bursts │
│  out : 4 x 114 bit bursts│
└─────────────────────────┘
             │
             ▼
┌─────────────────────────┐
│      Modulation          │
└─────────────────────────┘
             │
             ↯
```

Fig. 5

SUB BLOCKS:

BURSTS:

— = even bits in burst
--- = odd bits in burst
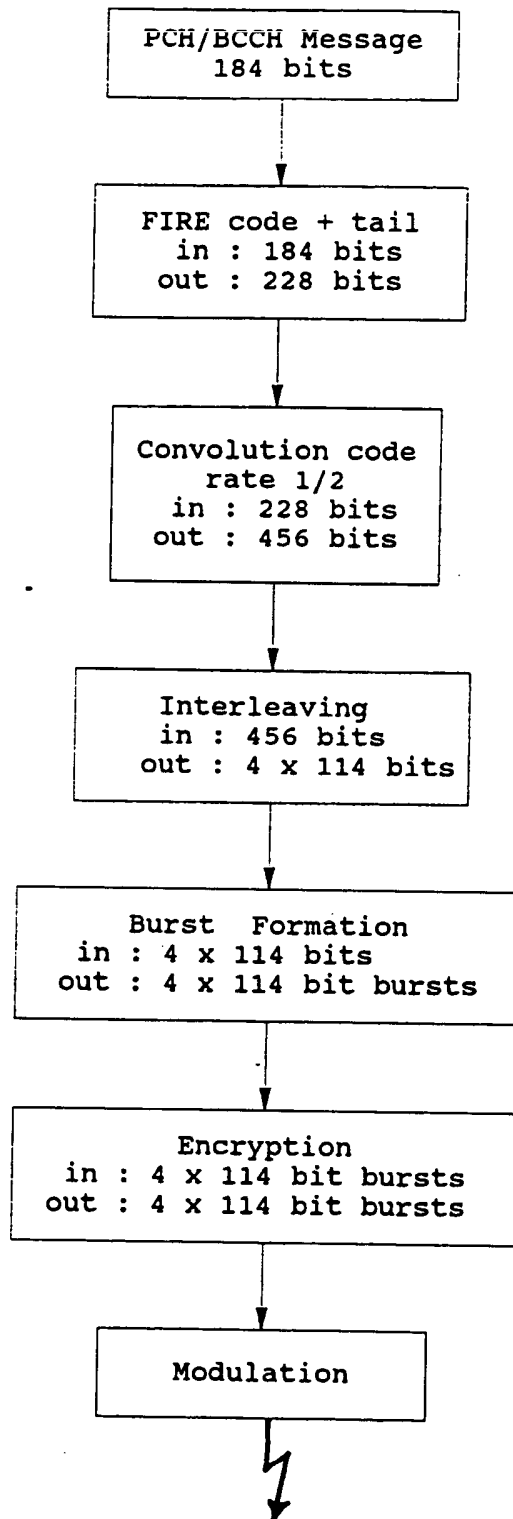
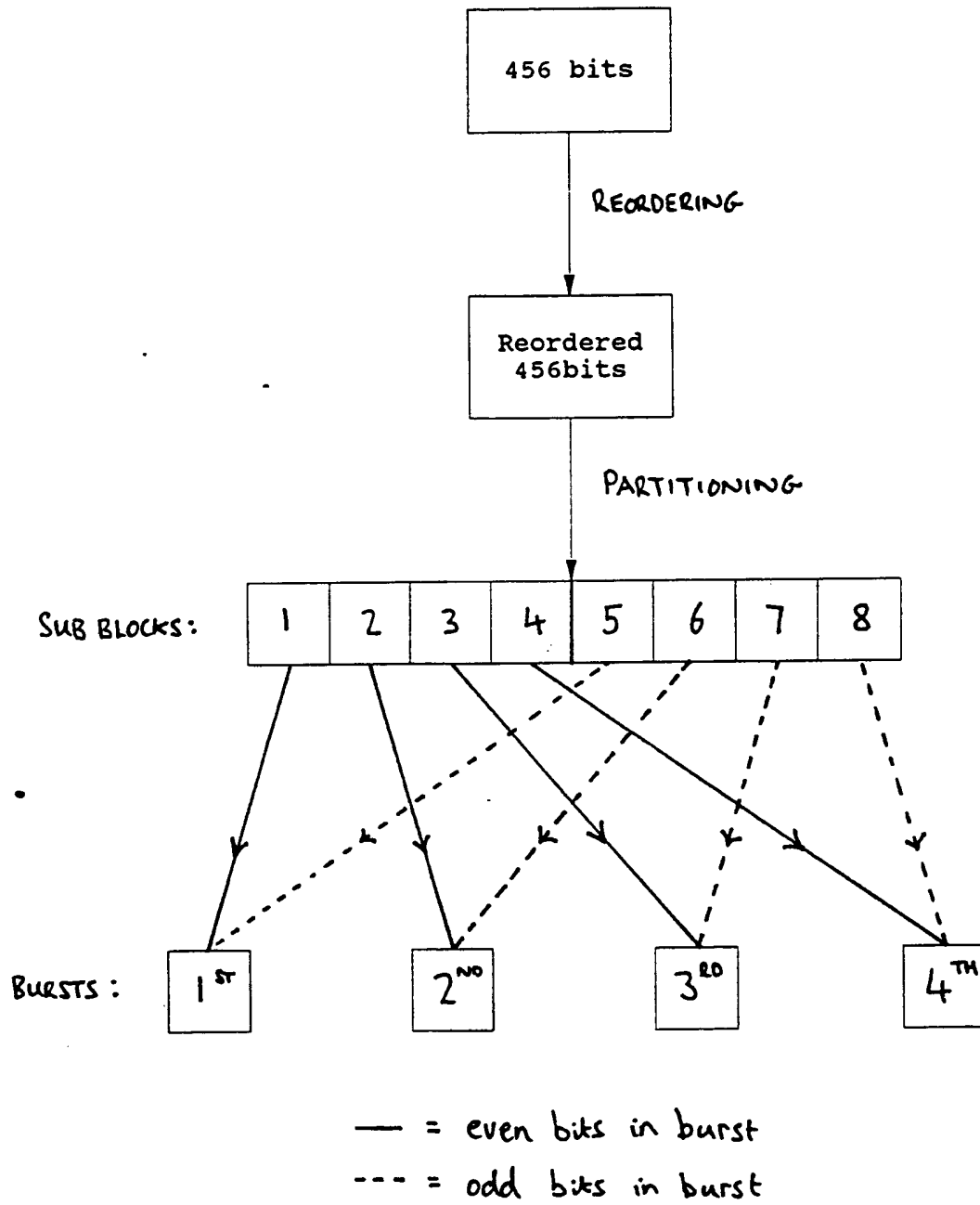# Fig. 6

```
*     10            DECONV
*
*
*     10.1          FUNCTIONAL DESCRIPTION
*     Subroutine for 2 slot deconvolution
      subroutine DECONV (bitbfr, symb)
*
*     10.2          VARIABLES
*     IMPLICIT NONE
*     10.2.1         EXTERNAL VARIABLES
*     10.2.1.1       INPUTS
      integer bitbfr (456)
*     10.2.1.1.      OUTPUTS
      integer symb (300)
*     10.2.2         LOCAL VARIABLES
      integer deco (2)
      integer orig  (0:300)
      integer ik,m,n,cl,c2,c3
*     10.2.3         COMMON VARIABLES
      REAL PI,PI2                    !* constants: pi & 2*pi
      COMMON/MATH/PI,PI2
      INTEGER DEBTX,DEBCH,DEBRX,DEBUG,DEBERR
      COMMON/DEBUG/DEBTX,DEBCH,DEBRX,DEBUG,DEBERR
      INTEGER LOGNUT, FITUNT,DTXUNT,DRXUNT,DEBUNT,DERUNT,DCHUNT
      COMMON/UNIT/LOGUNT,FITUNT,DTXUNT,DRXUNT,DEBUNT,DERUNT,DCHUNT
*
*     10.3  STRUCTURE
*     DECONV
*
*     10.4  MODULE
C     m: decoder uses odd (m=0) or even (m=2)
      m = 0
      cl = 0
      c2 = 0
      c3 = 0
      deco(1) = 0
      deco(2) = 0
      n = 1
      do ik = 1+m,456+m,4
            deco(1) = bitbfr(ik)
            deco(2) = bitbfr(ik+1)
            orig(n+3)    = deco(1).neqv.deco(2)
            orig(n+4)    = cl.neqv.c2.neqv.deco(1)
                cl       = c3
                c2       = orig(n+3)
                c3       = orig(n+4)
            n = n+2
      end do
      do n=1,228
            symb(n) = orig(n+4)
      end do
      RETURN
      END
```

(54)   **Reduction of power consumption in a mobile station**

(57)   The invention relates to a method for reducing the power consumption in a mobile system, the mobile system comprising a base station broadcasting messages such as signaling messages to the mobile stations. The stations comprising receiver means for receiving and processing messages broadcast from the base station. The signaling message is divided in parts and transmitted in a number of time slots in the TDMA system. First only a first predetermined part of a signaling message is received, and the signaling message broadcast from the base station is reconstructed on the basis of the part of the signaling message only, and the receiving of the rest of the signaling message is discontinued by switching at least a part of the receiver means of the mobile station in a power saving mode during the said period. If necessary, more information of the signaling message can be received before the reconstruction of the signaling message.

104 Kbps   13 Kbps   3   22.8 Kbps   271 Kbps
                         CHANNEL CODING   INTERLEAVING   4